NOTES

Hawaii as a Cloud Physics Laboratory

The major islands of the Hawaiian chain lie across the Pacific northeast trade winds near north latitude 21°, about 2,400 miles southwest of San Francisco. It is the purpose of this note to discuss very briefly the great advantages of one of these islands (Hawaii) as a place to study the relationships between the precipitation elements in clear marine air and these elements present in clouds formed in this air.

Recent developments in the study of rain formation have led to the hypothesis that large sea-salt particles are the basic nuclei upon which many raindrops initially form (Ludlam, 1951, Quart. Jour. Roy. Met. Soc. 77: 402–417; Woodcock, 1952, Jour. Met. 9: 200–212; Squires and Woodcock, MS.). These developments have re-emphasized the need in cloud physics for further detailed physical-chemical studies of rain which will enable us to ". . . know how nature operates to produce precipitation" (Byers, 1953, Indian Acad. Sci., Proc. 37(A): 237–247).

In order to make preliminary tests of the salt particle-raindrop hypothesis by making measurements of natural rains, it was necessary to find a geographic location where the contents of the lower atmosphere could be determined before, during, and after the formation of cloud and rain. Recent work has indicated that the windward side of the island of Hawaii, in the region of Hilo, is almost ideal for this study (see Fig. 1). Here, on most of the days throughout the year, rain falls near area A from orographic clouds which have formed over the island and within the trade-wind stream. If one follows the streamlines of this trade-wind air upwind of area A and over the sea, only scattered cumulus clouds are found upon arrival near area B. If the air is followed downstream from A, the clouds are found to dissipate, leaving clear air at C. Hence it is possible to determine, by appropriate measurement, the contents of a parcel of clear air at B, the nature of the precipitation within clouds formed in this air when it arrives at A, and the final modified parcel after the clouds have dissipated at C, a distance of about 30 miles.

Much of the mountain slope near Hilo is readily accessible on paved roadways. Rain and cloud drop sizes may be sampled within the orographic clouds from the 2,000 foot level to the 6,500 foot level on these roadways, thus avoiding the problems of evaporation, accretion, etc., which can greatly modify rains falling through clear air from cloud base to ground.

The presence of the trade-wind inversion at an average height of about 6,000 feet over the sea concentrates the clouds and water vapor in the lower air (Riehl *et al.*, 1951, Quart. Jour. Roy. Met. Soc. 77: 598–626; U.S. Weather Bureau, Staff Members, Honolulu, MS.; Leopold, 1949, Jour. Met. 6: 312–320). The inversion also limits the vertical extent of the salt nuclei, as shown in Figure 2. The distribution curves representing salt particles at the 1,550 and 2,740 meter altitudes show a great reduction in the number and weight of particles at the base of the inversion and above it (see temperature on insert diagram,

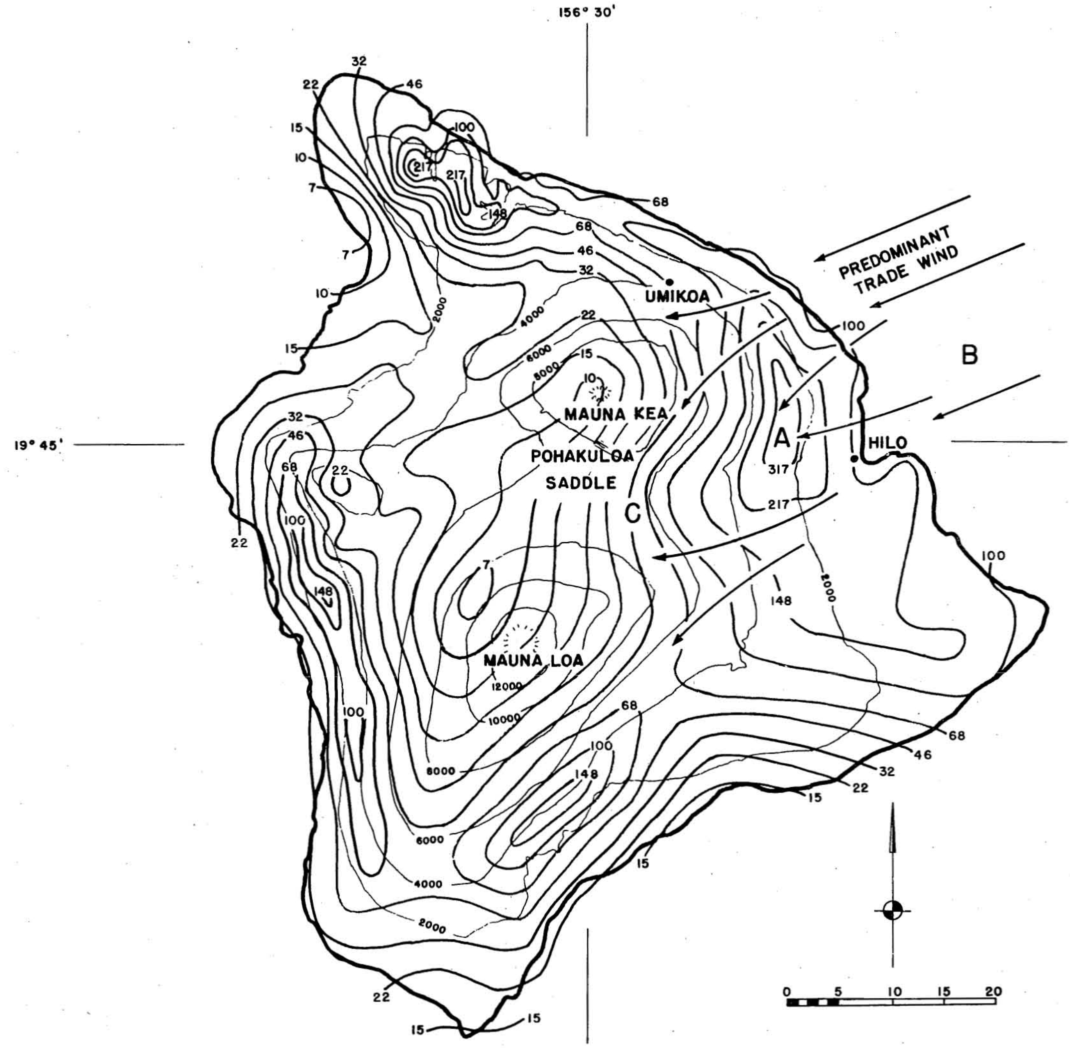

FIG. 1. Streamlines and mean annual rainfall on NE part of Hawaii. Isohyetal lines are in inches. The arrows represent the hypothetical mean streamlines of the flow of the trade winds in this part of the island, as given by Leopold (1949). (Scale in statute miles.)

Fig. 2). This concentration of the precipitation elements (i.e., clouds, water vapor, and nuclei) in the lower air is found during most of the year in this area and is one of the major advantages of Hawaii for precipitation studies such as those discussed here. Measurements of water vapor, temperature, salt nuclei, etc., can therefore be limited to the lower atmosphere, and there is usually no need to be concerned with the higher levels.

A further result of the presence of the trade-wind inversion is that the great majority of the clouds never ascend to heights at which the temperature is below freezing. Thus, most of the time there is no confusion as to whether or not the Bergeron rain-forming process may have occurred. It seems clear that accretional processes must account for practically all the rains in this region, and hence it is an excellent area in which to attempt to relate the

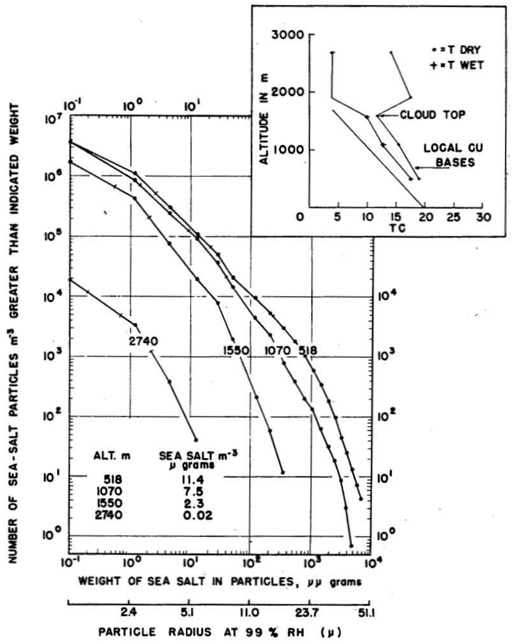

FIG. 2. Vertical distribution of sea-salt particles over the sea in Hawaii (21°30′N, 157°40′W), May 30, 1952, 1300 local time. Surface wind 80°, force 4 to 5. Height of scattered cumulus cloud bases varied from 690 to 820 meters. Temperature at 2,740 meters 12.8°C. The short transverse lines on the distribution curves mark the first quartile, median, and third quartile weight distribution points, reading left to right. The distribution curves are read as follows: at a height of 518 meters there are about 10,000 particles larger than 100 μμ grams.

detailed physical changes in the air associated with these frequently recurring processes.

The presence of the great mountain Mauna Kea (see Fig. 1), extending up to almost 14,000 feet, makes it possible to obtain direct visual estimates of maximum cloud heights among the orographic clouds over the high-rainfall region during extended time periods which make air craft observation impracticable. These estimates can be made at the same time that rain and cloud drops are being sampled within the cloud along the roadway below. One can drive a car up to a point at the 9,500 foot level, which is near a site overlooking the high-rainfall region A.

In this area of Hawaii, nature is producing rain very regularly and under simple conditions usually uncomplicated vertically by multiple layering of air masses of different origin and physical history. Geophysical events of the past and present seem to have fortuitously conspired to produce a setting in which simple natural experiments in rain-making are an almost daily occurrence. Through the use of local roadways and aircraft, the whole experimental area is readily accessible for study, and the observations of one day can commonly be tested or extended on the following day under the nearly constant natural conditions. The author knows of no other geographical setting so uniquely advantageous for cloud physics studies.

The importance of rainfall to the economy of the Hawaiian Islands has led to extensive activity by local organizations in the study of various weather factors and in the accumulation of data from numerous observing stations. These organizations—the U. S. Weather Bureau, the Pineapple Research Institute, the Experiment Station of the Hawaiian Sugar Planters' Association, and the Territorial Cattlemen's Council—located at Honolulu, Hawaii, are interested in fostering cloud physics research and are able to supply valuable climatological data from long-period records as well as current radiosonde and other data from numerous local stations. — *A. H. Woodcock, Woods Hole Oceanographic Institution.* (Contribution No. 660 of the Woods Hole Oceanographic Institution.)